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Abundance and morphometric relationships of Amazon shrimp - *Macrobrachium amazonicum* (Heller 1862) (Decapoda, Palaemonidae) - in an Amazon estuary - North coast of Brazil

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ABSTRACT. From *Macrobrachium amazonicum* (Heller, 1862) (Decapoda, Palaemonidae) abundance in monthly collections in the Amazon estuary and on Mosqueiro Island (State of Pará, Brazil) between April 2006 and August 2007, we verified that the site mentioned is favorable to the development of the species, since there is a significant number of young and adults specimens throughout the year, whose abundance is significantly higher in the dry season. Icoaraci was the site of great contribution in the total of specimens caught, relating this productivity to the large amount of organic matter in suspension. In this study, we found the largest *M. amazonicum* specimen ever collected, comparing to those mentioned by available scientific literature. The individual was a female caught on Combu Island with 44.72 mm carapace length or 18.45 cm total length. Relations of body mass (g) vs. carapace length (mm) for males, females and sexes together had negative allometry, which can be associated to the gonadal maturation cycle of the species. All other morphometric relationships showed positive allometry.

Keywords*:* Carapace; bio-ecology; population dynamics.

Abundância e relações morfométricas do camarão-da-Amazônia - *Macrobrachium amazonicum* (Heller, 1862) (Decapoda, Palaemonidae) - em um estuário amazônico - Costa Norte do Brasil

RESUMO. A partir da abundância de *M. amazonicum* de coletas mensais no estuário amazônico e Ilha do Mosqueiro (Pará-Brasil) entre abril/06 e agosto/07, foi verificado que o local citado é propício ao desenvolvimento da espécie, uma vez que há um expressivo número de jovens e adultos ao longo do ano cuja abundância é significativamente maior no período seco. Icoaraci foi o local de grande contribuição no total de espécimes capturados, relacionando-se esta produtividade à grande quantidade de matéria orgânica em suspensão. Neste estudo foi registrado o maior espécime de *M. amazonicum* já coletado, comparando ao citado pela literatura científica disponível. O indivíduo foi uma fêmea capturada na Ilha do Combu com 44,72 mm de comprimento da carapaça ou 18,45 cm de comprimento total. As relações massa corporal (g) *vs*. comprimento da carapaça (mm) para machos, fêmeas e sexos agrupados, tiveram alometria negativa, o que pode estar associado ao ciclo de maturação gonadal da espécie. Todas as demais relações morfométricas, apresentaram alometria positiva.

Palavras-chave: carapaça, bioecologia, dinâmica populacional.

1. Introduction

Macrobrachium (HELLER, 1862) (Palaemonidae) shrimps are widely distributed in various tropical and subtropical freshwater and brackish water environments in the world. In Brazil, these species are widely used in extensive farming due to their biological flexibility (BIALETSKI et al., 1997).

In the Amazon, *Macrobrachium amazonicum* is the main freshwater shrimp commercially exploited by small-scale fishing and consumed in the states of Pará and Amapá (ODINETZ COLLART, 1987) where yields are significant for the region. Despite this fact, studies on the bio-ecology of Amazon shrimp are punctual (BENTES et al., 2011).

Even recognizing the economic and ecological importance of this species in the Amazon, the life story of *Macrobrachium amazonicum* populations inhabiting coastal areas is still little understood (MACIEL; VALENTI, 2009). Particularly, in the Guajará Bay, except the works published by Silva et al. (2009) and Lucena Frédou et al. (2010), which analyzed the histology of *M. amazonicum* gonads and population dynamics, other scientific productions are limited, because they have not yet been published in indexed journals.

This way, the purpose of this study was to study the abundance and biometric and morphometric relationships of *Macrobrachium amazonicum* in the Guajará Bay and Mosqueiro Island (State of Pará), contributing to the knowledge of this species' bio-ecology.

2. Materials and Methods

Sampling was carried out in six sites, including four of them in the Guajará Bay and the others on Mosqueiro Island, comprising a distance of 30 km in a straight line. This estuary receives a considerable contribution of organic matter arising in part from leaching and domestic sewage. According to Viana (2006) this fact gives the waters muddy aspect and yellow-greenish color, allowing light penetration. In addition, waters are influenced by ocean tides, becoming brackish waters in the lower course (PAIVA et al., 2006). The dynamics of tides are influenced by river and oceanic flows culminating in periods of large tides and the substrate is composed of sand and mud (fluid and compact) (GREGÓRIO; MENDES, 2009). These characteristics give Guajará estuary and Mosqueiro Island (Pará) a peculiar environment -though little known- housing a wide variety of marine and freshwater species, many of them of interest for consumption (PAIVA et al., 2006).

Amazon shrimps were obtained through monthly collections (May 2006 to August 2007) on the waterfront of Belém, Combu Island, Icoaraci district, Arapiranga Island, and Mosqueiro Island (Furo das Marinhas and Port of Pelé) (Figure 1). The sites were chosen to represent a gradient of exposure to the sea and the degree of anthropogenic influence. Mosqueiro, Icoaraci and Belém suffer direct influence of domestic sewage and industrial effluents from the city, according to data of hydrodynamics and water quality by Viana (2006). The remaining sites were chosen to represent similar sites in the environment; however, more preserved from direct anthropogenic impacts. In addition, we attempted to carry out the collections in sites where fishermen live almost exclusively from this resource and supply the local market and the city of Belém (Pará).

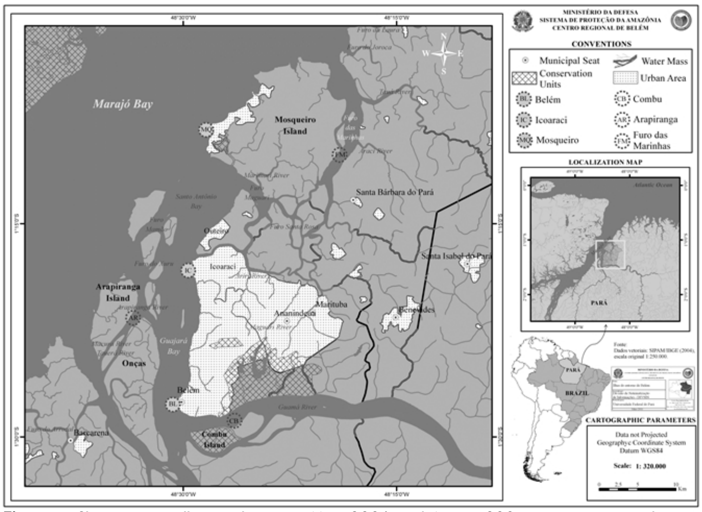

Figure 1. Shrimp sites collection, between May 2006 and August 2007, in Pará´s coastal zone. MQ = Mosqueiro Island (Port of Pelé); FM = Furo das Marinhas (Mosqueiro Island); AR = Arapiranga Island; IC Icoaraci district; BL Belém; CB = Combu island. The symbols pointed by the arrows are the places of anthropic interference according to Viana (2006). / **Figura 1.** Locais de coleta de camarões, entre Maio/2006 e Agosto/2007, na zona costeira paraense. MQ = Ilha de Mosqueiro (Porto do Pelé); FM = Furo das Marinhas (Ilha de Mosqueiro); AR = Ilha do Arapiranga; IC = Distrito de Icoaraci; BL = Belém; CB = Ilha do Combu. Os símbolos apontados pelas setas são os locais de maior interferência antrópica segundo VIANA (2006).

The samples were collected with traps -locally called matapis, which are made of natural fibers and recycled PET bottles- placed in pairs two days before the new moon, at the last low tide of the day. Three matapis sizes were used, a pair of each by site of collection. In the first low tide next day, the matapis were collected, totaling 12 hours permanence in the water of fishing gear. Additionally, we checked the water surface temperature (°C) with a thermometer and salinity with an optical refractometer, before and after the collection of shrimps, always at the same time in both cases.

The following measures were taken in all M. amazonicum: carapace length - CL (measured from the back of the orbit to the rear edge of the carapace); total length - TL (measured between the front end of the rostrum to the rear end of the telson); cephalothorax length - CefL (measured from the rear edge of the carapace until the front portion of the rostrum); cheliped length - CL (length of the second pair of chelipeds from the front part of the dactylus [fixed or mobile finger] up to the thigh); and abdomen length - AL (from the central portion of the dorsal region of the front margin of first abdominal somite to the end of the telson). Weight of each individual was assessed with a 0.01 g precision scale. Sex was determined by observation of the endopods morphology of the second pair of pleopods as proposed by Ismael and New (2000).

A sampling unit was considered a set of three matapis (one of each size) per site and month of collection. For each situation, we recorded two replicas, totaling 204 samples (17 local *6 months *2 samples).

The abundance average of carapace length (mm) and average biomass (g) of *Macrobrachium amazonicum* shrimps were tested separately through ANOVA (one-way and factorial) or Kruskall-Wallis one-way analysis of variance, in function of the sites, sexes and year seasons: dry (DR): July to September; rainy (RA): December to April; dry/rainy transition (DRT): October to November; rainy/dry transition (RDT): May to June. In each case, we used Tukey's post-hoc test.

We carried out hierarchical clustering analysis using Bray Curtis's dissimilarity and UPGMA (unweighted pair group method with arithmetic mean) as distance measurement in order to identify the similarity of the sites studied regarding abiotic factors (temperature and salinity) and shrimp abundance related to the sites and periods of the year.

The analysis of multidimensional scaling (MDS) was used for the similarity spatial plot of samples abundance between periods and sites, by means of bi-dimensional correlation. The first two MDS dimensions were later used as dependent variables in a canonical correlation analysis. For this, we considered those correlations with values greater than 0.7 as significant.

For morphometric analyses we carried out regressions between carapace length (CL) -independent variable- and body weight (mass in grams) of shrimps -dependent variable, separated by sex in each site. The values of constants 'a' and 'b' of the exponential equation obtained for this relationship ($Y = a. X^b$) that express the condition factor and the level of allometry respectively, were tested through Student's t-test ($p<0.01$). For all other morphometric relationships -the different measures of shrimps size- we used the regression linear model ($Y = a+bX$).
Data analysis was performed by the STATISTICA program (StatSoft Inc. 2007) and PRIMER 6.0 (CLARKE, 1994; WARWICK, 2001).

3. Results

The temperature at the sampling sites varied between 25 °C and 28 °C, and the average for all sites was 26.5 °C. Average temperature differed significantly between sites ($F = 8.642$; $p<0.01$) and between months ($F = 94.8$; $p<0.01$) and temperature in Icoaraci district (IC) and Furo das Marinhas (FM) were different from the others ($p<0.01$), showing the major averages (Figure 2). March had the lowest average ($p<0.01$).

Average salinity ranged from zero to eight. No significant difference was observed regarding salinity averages between sites ($F = 0.6518$; $p>0.05$), and overall average was 1.35 (Figure 2). However, salinity differed significantly between months (Figure 3). Increased salinity was evident during less rainy months (August to October), due to the decrease of river discharges.

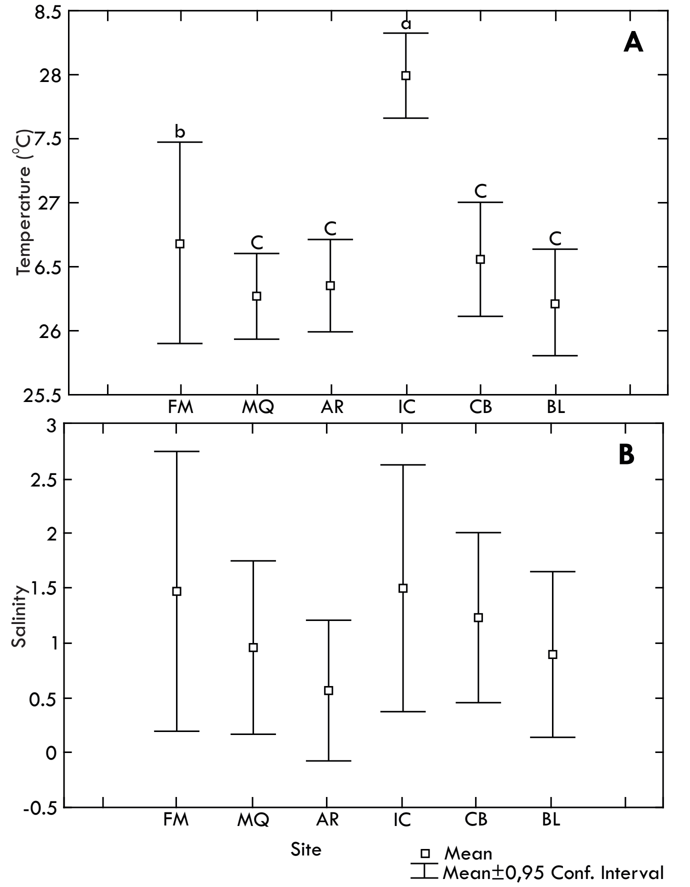

Figure 2. Average values ± 95 confidence interval of the abiotic factors (A = temperature and B = salinity) in the area of study from May 2006 to September 2007. FM = Furo das Marinhas (Mosqueiro Island); MQ = Mosqueiro Island (Port of Pelé); AR = Arapiranga Island; IC = Icoaraci; CB = Combu Island; BL = Belém. The letters above each box plot indicate if there are difference or not between the sites (Tukey's Test), same letters with indicate no significant difference. / **Figura 2.** Valores médios ± 95% intervalo de confiança dos fatores abióticos (A = temperatura e B = salinidade) na área do estudo entre Maio/2006 e Setembro/2007. FM = Furo das Marinhas (Ilha de Mosqueiro); MQ = Ilha de Mosqueiro (Porto do Pelé); AR = Ilha do Arapiranga; IC = Icoaraci; CB = Ilha do Combu; BL = Belém. As letras acima de cada box plot indicam se há diferença ou não entre os locais (Teste de Tukey), letras iguais, sem diferença significativa.

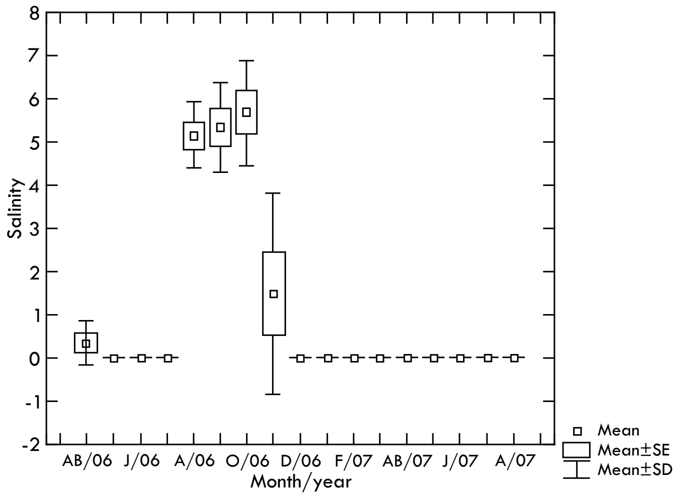

Figure 3. Average values, error (SE) and standard deviation (SD) of monthly salinity in an Amazon estuary between April 2006 and August 2007. / **Figura 3.** Valores médios, erro (SE) e desvio padrão (SD) da salinidade mensal em um estuário Amazônico entre Abril/2006 a Agosto/2007.

When temperature and salinity were tested by ordering analysis per month and site, two groups were clearly formed (Figure 4). Group A includes dry season samples and Group B rainy season samples, denoting that sites are very similar to each other. Fluctuations in temperature and salinity vary most depending on rainfall rather than on sampling sites (Table 3).

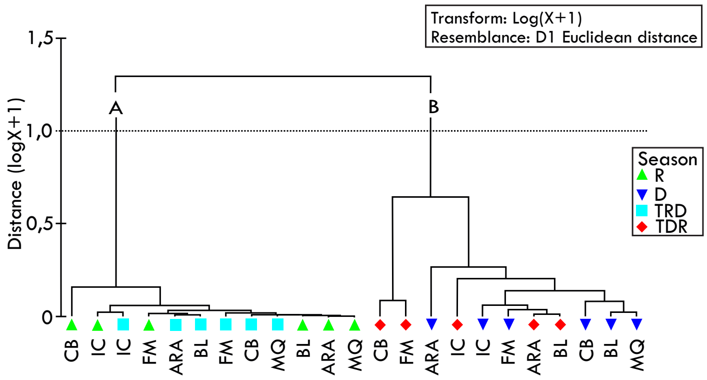

Figure 4. Dendrogram of cluster analysis obtained through UPGMA (unweighted pair group method with arithmetic mean) and Bray Curtis similarity based on abiotic factors (temperature and salinity) in the Guajará Bay and on Mosqueiro Island (Pará) between April 2006 and September 2007. CB = Combu Island. ARA = Arapiranga Island; IC = Icoaraci; FM = Furo das Marinhas (Mosqueiro Island); MQ = Mosqueiro Island; BL = Belém; Seasons: R = Rainy; D = dry; TDR = dry-rainy transition; TRD = rainy-dry transition. / **Figura 4.** Dendrograma da análise de *cluster* obtida através da UPGMA (*unweighted pair group method with arithmetic mean*) e similaridade de Bray Curtis baseada nos fatores abióticos (temperatura e salinidade) da Baía do Guajará e Ilha do Mosqueiro (Pará), entre Abril/2006 e Setembro/2007. CB = Ilha do Combu. ARA = Ilha do Arapiranga; IC = Icoaraci; FM = Furo das Marinhas (Ilha de Mosqueiro); MQ = Ilha de Mosqueiro; BL = Belém; Períodos: C = chuvoso; S = seco; TSC = transição seco para chuvoso; TCS = transição chuvoso-seco.

The biggest monthly catch records were observed in Icoaraci district, with 364 specimens in December 2006 and 289 in August 2007. Combu Island was in second place with 255 specimens caught in June 2006. The variation of the amount of specimens caught by site and month seems to be a pattern, i.e., the largest catches take place in the first half of the year in Belém and for the other islands from the end of the first half to the middle of the second half, showing an apparent annual synchrony of the volume caught towards the inside mouth of the Bay.

Since the sites are similar, the abundance of *Macrobrachium amazonicum* (n=9118) did not differ significantly between sites (H=11.23; $p>0.01$), but between months (F=2.25; $p<0.01$). The amount of shrimps caught in the first year (April to December 2006) was higher at non-anthropized sites (Figure 5) and in the second year (January to August 2007) there was a higher peak in Icoaraci (Figure 5) which is one of the sites considered anthropized.

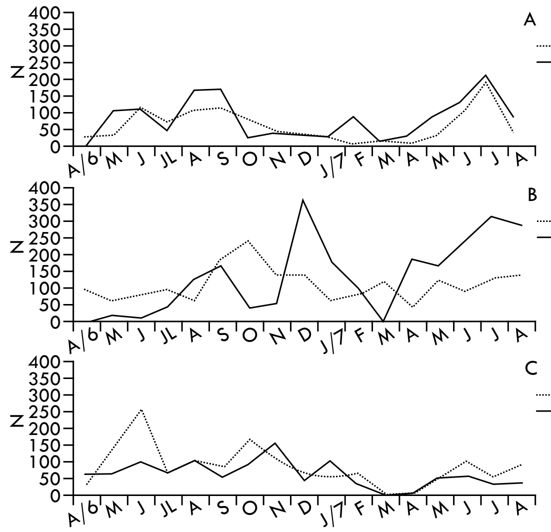

Figure 5. Variation of the total number of *M. amazonicum* caught in the Guajará Bay (Pará) and on Mosqueiro Island (Pará) between January/2006 and August/2007. A = Furo das Marinhas (FM) and Mosqueiro Island (MQ); B = Arapiranga Island (AR) and Icoaraci district (IC); C = Combu Island (CB); and Belém (BL). Continuous line = greater anthropization; dotted line = less anthropization. / **Figura 5.** Variação do número total de *M. amazonicum* capturados na Baía do Guajará (PA) e Ilha de Mosqueiro (PA, Brasil) entre Janeiro/2006 e Agosto/2007. A = Furo das Marinhas (FM) e Ilha do Mosqueiro (MQ); B = Ilha do Arapiranga (AR) e Distrito de Icoaraci (IC); C =Ilha do Combu (CB); e Belém (BL). Linha contínua = maior antropização; linha pontilhada = menor antropização.

Making a cut of approximately 60% in cluster analysis (Figure 6), two groups are formed as to the amount of shrimp caught: I - which includes most dry season samples; II - other samples that include the rainy and transition seasons between both seasons (dry and rainy) (Figure 6). The largest catches took place during the dry season (N = 3430).

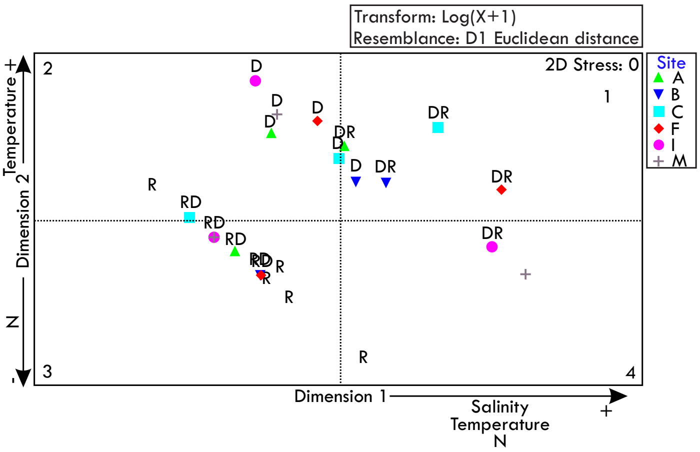

Figure 6. Multidimensional Scaling (MDS) of *M. amazonicum* specimen's abundance in an Amazon estuary (Brazilian Amazon) in relation to seasonal periods from April 2006 to August 2007. A: Arapiranga Island; B: Belém; C: Combu Island; F: Furo das Marinhas (Mosqueiro Island); I: Icoaraci; M: Mosqueiro Island (Port of Pelé). Periods: R: rainy; D: dry; DR: dry-rainy transition; RD: rainy-dry transition. The arrows indicate the direction in which there was a growing trend (+) and descending (-). / **Figura 6.** Escalonamento multidimensional (MDS) da abundância de *M. amazonicum* em um estuário amazônico (Amazônia brasileira) em relação aos períodos sazonais, de abril/2006 a agosto/2007. A: Ilha do Arapiranga; B: Belém; C: Ilha do Combu; F: Furo das Marinhas (Ilha de Mosqueiro); I: Icoaraci; M: Ilha de Mosqueiro (Porto do Pelé). Perídos: C: chuvoso; S: seco; SC: transição do seco para o chuvoso; CS: transição do chuvoso para o seco. As setas indicam o sentido em que há a tendência crescente (+) e decrescente (-).

Cluster analysis (Figure 6), MDS (Figure 7) and later correlation of results through a canonical analysis (Table 1) proved to be sensitive to the relationship between the number of individuals caught and the abiotic factors (temperature and salinity), showing that the number of individuals caught was greater in higher temperatures (dry season). Positive correlations were found in the number of specimens caught in relation to salinity and temperature (dimension 1).

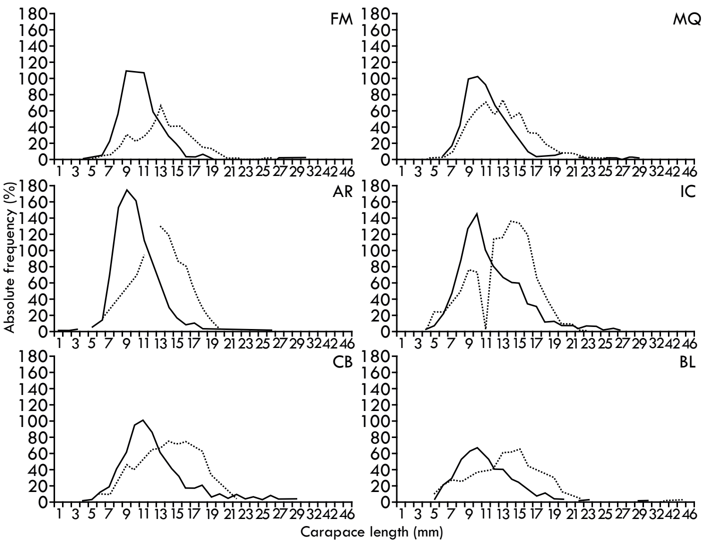

Figure 7. Size frequency distribution of Amazon shrimp collected between April/2006 and August/2007. Males: continuous line; Females: dashed line. FM: Furo das Marinhas (Mosqueiro Island); MQ: Mosqueiro Island (Port of Pelé); AR: Arapiranga Island; IC: Icoaraci; CB: Combu Island; BL: Belém. / **Figura 7.** Distribuição de frequência de tamanho dos camarões-da-Amazônia coletados entre Abril/2006 e Agosto/2007. Machos: linha contínua; Fêmeas: linha tracejada. FM: Furo das Marinhas (Ilha de Mosqueiro); MQ: Ilha de Mosqueiro (Porto do Pelé); AR: Ilha do Arapiranga; IC: Icoaraci; CB: ilha do Combu; BL: Belém.

Table 1. Results of canonical correlation analysis between environmental variables (temperature and salinity) and amount of individuals of *M. amazonicum* caught in the Guajará Bay (Pará) and on Mosqueiro Island between April/2006 and August/2007. Values greater than 0.7 are highlighted in bold. / **Tabela 1.** Resultados da análise de correlação canônica entre as variáveis ambientais (temperatura e salinidade) e quantidade de indivíduos de *M. amazonicum* capturados na Baía do Guajará (PA) e Ilha de Mosqueiro entre Abril/2006 e Agosto/2007. Valores maiores que 0.7 foram destacados em negrito.

Sites	Variables	Dimension 1	Dimension 2
Arapiranga Island Combu Island Furo das Marinhas	Salinity	**0.861**	0.115
	Temperature	**0.701**	0.377
	Number of individuals	**0.701**	0.035
Belém Icoaraci district Mosqueiro Island	Salinity	-0.483	0.699

Quadrants 1 and 2 in Figure 7 include the majority of sampling carried out during dry seasons and their transition to rainy seasons, in which the number of individuals caught was high in most cases. Quadrants 3 and 4 of the same Figure include most samples of rainy seasons and their transition to dry seasons, in which the number of individuals caught was smaller.

A total of 9077 shrimps had the carapace length measured. The amplitudes of size and mass, as well as averages and pattern deviations for males, females and sexes together are summarized in Table 2. In all cases, females were larger and heavier than males. Specimens with the largest carapace length (CL) were caught on Combu Island, with an average of 13.7 (±3.94 mm confidence interval). The specimens with the largest body mass were also captured on Combu Island, whose average was 2.3 (±1.89 g). The major averages of CL (F=20.44; $p<0.01$) and body mass (F=10.75; $p<0.01$) were observed in non-anthropized sites (Combu, Arapiranga and Furo das Marinhas islands [Mosqueiro Island]).

Table 2. Variation of carapace length and mass of Amazon shrimps specimens collected in the Guajará Bay and on Mosqueiro Island (Pará). N= number of specimens collected in each category; CL= carapace length; PD= pattern deviation; F= female; M= male; IND= indeterminate sex; and T= total. / **Tabela 2.** Variação do comprimento da carapaça e massa dos espécimes de camarão-da-Amazônia coletados na Baía do Guajará e Ilha de Mosqueiro (PA). N= número de exemplares coletados em cada categoria; CC= comprimento da carapaça; DP= Desvio padrão; F= fêmea; M= macho; IND= sexo indeterminado; e T= total.

sex	CL (mm)					Mass (g)			
	N	Average	PD	Min	Max	Average	PD	Min	Max
IND	465	11.36	3.39	3.09	30.22	1.27	1.09	0.02	12.37
F	4471	14.80	2.84	2.57	44.72	2.88	1.37	0.04	13.80
M	4181	12.95	1.78	1.55	34.23	1.96	0.91	0.02	22.07
T	9118	12.88	3.68	1.55	44.72	1.97	1.69	0.02	22.07

Average size (CL) differed significantly between sites (F = 21.99; $p<0.01$) - Combu Island had the highest average of this length in relation to the other sites ($p<0.05$) - and also between sexes (F = 335.58; $p<0.01$) –females were larger than males. This size variation was also observed during the periods of the year (F = 40.37; p 0.01) and smaller individuals were recorded in the dry season. The lengths also differed regarding the relationship site*season, site*sex, season*sex, and site*season*sex (Table 3). In all cases, females on Combu Island were always larger during rainy and rainy-dry transition seasons (Table 3).

Table 3. Two-way ANOVA results of carapace length (CL mm) and body mass (g), separately, in relation to collection sites and sex in the Guajará Bay (Pará) between April/2006 and August/2007. P^1= probability resulting from ANOVA; P^2= probability by Tukey's test; CI= Combu Island; IC= Icoaraci; MQ= Mosqueiro Island; D= dry season; R= rainy season; RD= rainy/period transition to dry transition season. / **Tabela 3.** Resultados de ANOVA dois critérios do comprimento da carapaça (CC mm) e massa corpórea (g), separadamente, em relação aos locais de coleta e sexo na Baía do Guajará (PA) entre Abril/2006 e Agosto/2007. P^1= probabilidade resultante da ANOVA; P^2= probabilidade do teste de Tukey; CB= ilha do Combu; IC= Icoaraci; MQ= Ilha de Mosqueiro; S= período seco; C= período chuvoso; CS= transição período chuvoso para seco.

Variable	Source of variation	SS	DF	MS	F^1	P^1	P^2	Tukey
								Meaning
CL	Site	1473	5	294.6	21.99	<0.01	<0.05	> CB
	Sex	123E2	3	4091	335.58	<0.01	-	Female>Males
	Season	1620	3	539.9	40.37	<0.01	<0.01	< D
	Site * season	5166	15	344.4	7.8	<0.01	<0.01	> CB - D
	Site * sex	1095	15	73	6.3	<0.01	<0.01	> Female - CB
	Season * sex	399	9	44	4.9	<0.01	<0.01	> Female - R and RD
	Site * season * sex	959	37	26	2.3	<0.01	<0.01	> Female - R and DR - CB
Mass	Site	220.2	5	44.04	15.53	<0.01	<0.05	> CB
	Sex	2056	3	685.5	259.8	<0.01	-	Females>Males
	Season	480.4	3	160.1	57.05	<0.01	<0.01	< D
	Site * season	1233	15	82.2	30.89	<0.01	<0.01	> IC - MQ
	Site * sex	215	15	14.3	5.5	<0.01	<0.01	> Females - IC and MQ
	Season * sex	91	9	10.1	3.9	<0.01	<0.01	> Females - RD
	Site * season * sex	263.5	37	7.1	2.9	<0.01	<0.01	> Females - RD - MQ

The average biomass differed between sites (F= 15.53; p<0.1), with the heaviest specimens captured on Combu Island compared to those from other sites (p<0.05). Similarly to the size, females were heavier than males (F= 259.8; p<0.01) in Icoaraci and Mosqueiro (Tukey p<0.01) especially in the rainy/dry transition season (Tukey p<0.01). The specimens with smaller biomass were caught during the dry season (Tukey p<0.01).

The relationship between biomass and the carapace length of males, females and sexes together always showed negative allometric growth (p<0.01) (Figure 8), that is, the body weight increases to a lesser extent than the carapace length. This difference was statistically significant between males, females and sexes together (t= 172.046; p<0.001). Coefficient 'a', which represents the level of 'weight gain' or fattening of the species, also showed statistically significant difference between sexes - separated and together- (t= 176.666; p<0.001) and males had greater value ('a'= 0.0022) than females.

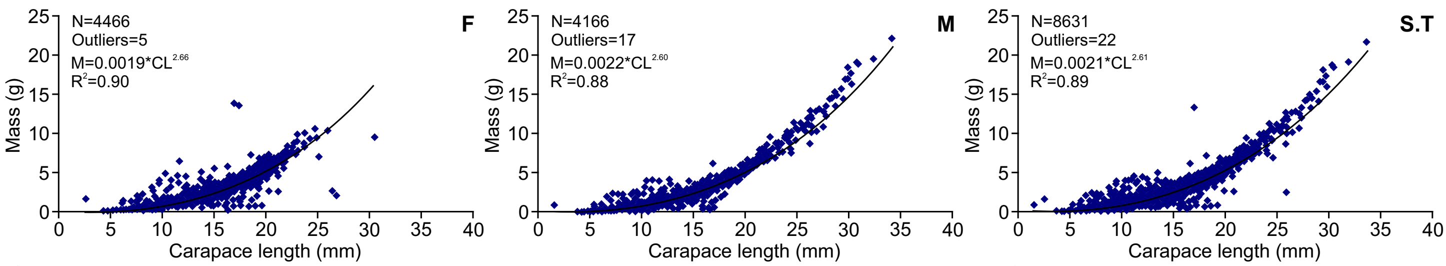

Figure 8. Relationship between carapace length (CL - mm) and biomass (M - g) of Amazon shrimp by sex; collected between April 2006 and August 2007 in the Guajará Bay and on Mosqueiro Island (Pará). F= females; M= males; S.T. sexes together. / **Figura 8.** Relações entre o comprimento da carapaça (CL - mm) e a biomassa (M - g) do camarão-da-Amazônia por sexo, coletados entre Abril/2006 e Agosto/2007 na Baía do Guajará e Ilha de Mosqueiro (PA). F= fêmeas; M= machos; S.A. = sexos agrupados.

In all relationships between the carapace length and the other morphometric variables, allometry was positive -the angular coefficient of regression was different and greater than 1 (linear relations) - that is, the value of Y increases in higher proportion than X (Table 4).

Table 4. Regression equations for relationships of CL (carapace length) with the variables AL = abdomen length; CCef= cephalothorax length; ChL= second cheliped length; Cte= telson length; and TL= total length of *M. amazonicum* collected between April 2006 and August 2007 in a Brazilian Amazon estuary. N = number of individuals; Y= dependent variable; X= independent variable (carapace length); a= line intersection in Y; b= angle of inclination of the line and coefficient of allometry; r^2= coefficient of determination; F#= Test F; F= females; M= males; T= total (sexes together); A= allometry: [(+) positive allometry, (-) negative allometry]. / **Tabela 4.** Equações de regressão para as relações de CL (comprimento da carapaça) com as variáveis CA= comprimento do abdome; CCef= comprimento do cefalotórax; CQ= comprimento do segundo quelípode; Cte= comprimento do télson; e CT= comprimento total de *Macrobrachium amazonicum* coletado entre Abril/2006 e Agosto/2007 em um estuário da Amazônia brasileira. N= número de indivíduos; Y= variável dependente; X= variável independente (comprimento da carapaça); a= intersecção da reta em Y; b= ângulo de inclinação da reta e coeficiente de alometria; r^2= coeficiente de determinação; F#= Teste F; F= fêmeas, M= machos, T= total (sexos agrupados); A= alometria: [(+) alometria positiva, (-) alometria negativa].

Relationship	Group	N	Y=a+b.X	r^2	F#	A
AL X CL	F	2452	AL = 1.58CL+3.85	0.89	20985*	+
	M	531	AL = 1.42CL+5.97	0.87	493.2321*	+
	T	4844	AL = 1.59CL+3.61	0.86	182.2081*	+
Ccef X CL	F	2612	Ccef = 2.06CL+2.23	0.87	66.01575**	+
	M	521	Ccef = 1.99CL+3.98	0.88	3766.799*	+
	T	5435	Ccef = 2.03CL+2.95	0.87	367.6307*	+
ChL X CL	F	1458	ChL = 2.16CL+0.29	0.76	4660.907*	+
	M	312	ChL = 3.56CL-15.41	0.74	888.4073*	+
	T	2946	ChL = 2.59CL+4.74	0.72	7466.882*	+
TL X CL	F	2437	TL = 3.89CL+10.65	0.83	11814.62*	+
	M	2492	TL = 3.91CL+11.23	0.85	43.00987*	+
	T	5008	TL = 3.88CL+11.16	0.84	121.4351*	+

* p<0.01; ** 0.01<p<0.05.

4. Discussion

The variations of temperature and salinity in the Guajará Bay follow a pattern known to the entire Amazon estuary. The tidal flow raises the water level up to 4 m during the rainy season due to the additive effect of oceanic reflux and high water discharge of the river at this time of year (ALMEIDA et al., 2004). This feature is responsible for the prevalence of certain freshwater and marine species (CAVALCANTE, 2008).

The average temperature of Guajará Bay (26.5 °C) did not differ from that found by Silva et al. (2002) in Vigia (North of Brazil) which was 27 °C and 27.5 °C in the rainy season and 28 °C in the dry season (1999, 2000 and 2001).

Average salinity values were also very close to those found by Silva et al. (2002), whose average was 1 for the rainy season and 5 for the dry season. However, the Guajara Bay is under total influence of the local water network, contributing to the low values of this parameter. This variation over the seasons classifies the environment as oligohaline, with average salinity between 0.5 and 5. On the other hand, the region has three zones easily detectable: 1) limnetic zone – the area around Combu and Belém islands, whose salinity is usually less than 1; 2) oligohalinic zone – comprises the area from Icoaraci to Arapiranga Island (salinity between 1 and 5); 3) mesohalinic zone – the upper section of the estuary which includes Mosqueiro Island, with salinity greater than 5 and less than 18 in the greater part of the year.

All the sites studied showed to be suitable, considering the abundance of *Macrobrachium amazonicum*. Many species of this genus are considered euryhaline and eurytermic (HERRERA et al., 1998). Adults of *M. acanthurus familia*, for example, live in freshwater and brackish environments with temperatures greater than 15 °C and under 42 °C, showing an excellent osmoregulation ability (HERRERA et al., 1998). However, during larval development, these characterize a low tolerance to salinity. The early stages of *M. acanthurus* and *M. carcinus* are euryhaline familia, but they become stenohaline during larval development (CHOUDHURY, 1971a; CHOUDHURY, 1971b). In the case of *M. amazonicum*, the larvae can develop at temperatures of 26.4 °C up to 28.7 °C in laboratory (MAGALHÃES, 1985); besides the fact that, according to Maciel and Valenti (2009), larvae of this species have not been found in estuarine areas, although there are records of occurrence in an estuary in the State of Pará, Brazil (MARTINELLI et al., 2005). This last information corroborates with Albertoni et al. (1999), who claims the dependence of some *Macrobrachium* larvae on closing of the reproductive cycle in a coastal lagoon in the State of Rio de Janeiro.

Fauna caught throughout the study period was extremely related to rainfall that influences directly the mixture of salts, characterizing differentiated environments. Due to this characteristic, besides shrimps and fish, other crustaceans as crabs were also collected (CAVALCANTE, 2008). Records of other *Palaemonidae* in the entire coastline of Pará, as *M. carcinus*, *M. surinamicum* and *M. rosenbergii* have been reported by several authors, including Barros and Silva (1997) and Silva et al. (2002), in the Guajará Bay, few works were directed to the richness and diversity of crustaceans species.

The abundance of *Macrobrachium amazonicum* in experimental catches was significantly greater in the dry and rainy/dry transition seasons, agreeing with Silva et al. (2002). This seasonal variation had already been cited by Odinetz Collart (1993) when he observed that in floodplain lakes of the Amazon basin maximum catches occur during droughts and minimum during floods, due to a large spatial dispersion of individuals with the increased volume of water. The same author also states that on the Amazon River bank, maximum catches are observed during droughts, when shrimps migrate out of the floodplain lakes and minimum catches during floods, due to the very high speed of water flow, which is reflected in the catchability of the species.

The greatest abundances were recorded in Icoaraci. This fact may be related to the amount of suspended matter registered at this site, since it is an area of intense fishing activity and there is also deposition of food industries sewers, contributing to an 'enrichment' of this site with material of organic origin, which can be providing the population increase. However, it is an area of intense human activity, possibly resulting in a high degree of local contamination. This fact cannot be referenced as an advantage, but a justification for studying the long-term effects of changes in biotic communities. Pollution in Icoaraci suggests that there is a possible beginning of an eutrophication process, i.e., a gradual increase of the amount of nutrients (primarily chemical compounds rich in phosphorus and nitrogen) due to the amount of domestic and industrial effluents in the area (VIANA, 2006).

This phenomenon would contribute to the excessive proliferation of microorganisms and the consequent deterioration of water quality, making it poor in oxygen. For the Amazon shrimp, the low amount of oxygen does not seem to be a limiting factor; on the contrary, when Montoya (2003) studied the species *M. amazonicum*, *M. surinamicum* and *M. jelskii* at the delta of the Orinoco River (Venezuela), associated with the 'water hyacinth' (*Eichhornia crassipes* - free-floating aquatic plant), found that where the amount of dissolved oxygen was smaller, the greater was the participation of *M. amazonicum* in the faunal composition. Similarly, Mallasen and Valenti (2006), studying the effects of amount of nitrite in larval development of *M. rosenbergii* concluded that, probably under high concentrations of this chemical compound, the species allocate energy to adjust their physiological mechanisms against the toxic effects of nitrite by reducing weight gain or decreasing the number of metamorphoses. Eventually, this strategy can be common to all species of *Macrobachium*; however, this statement still needs to be studied in greater detail.

Albertoni et al. (2003), studying the natural diet of three species of shrimp (*Farfantepenaeus brasiliensis*, *F. paulensis* and *Macrobrachium acanthurus*) in Rio de Janeiro (Imboassica

Laggon), concluded that the largest part of this species' diet consists of wastes and filamentous algae. Due to the fact that the amount of pollution in Icoaraci is comparable to the amount in Imboassica lagoon, in the state of Rio de Janeiro, it is suggested that the proliferation of algae at this site is also significant, as well as the amount of inorganic and organic waste. Thus, it is believed that the diet of *M. amazonicum* is not as differentiated from the diet of *M. acanthurus*, what contributes to the mass catch of the first species in Icoaraci (Pará). Studies for evaluation of the stomach contents of *M. amazonicum* will allow confirming or refuting this hypothesis.

Both groups delimited by cluster analysis of samples abundance differentiate clearly the volume of specimens catch: I – includes most samples of the dry season in which the highest values of salinity and water temperature were observed, and II – the other samples that include the rainy seasons and transition between both seasons (dry and rainy). This pattern is consistent with the previous topic discussed and with the studies carried out by Lima et al. (2001) in the largest public dam in the State of Pernambuco, Poço da Cruz (Ibimirim - PE) and Odinetz Collart and Moreira (1993) in floodplain environments of the Amazon basin.

According to Odinetz Collart and Moreira (1993), the variation of Amazon shrimp catches depends on the flood intensity of the same year, which affects the survival and growth of individuals. The expansion of aquatic macrophytes during floods reduces intra-specific competition, increasing the amount of microhabitats for larvae and the introduction of suspended material increases the productivity of the floodplain lakes (ODINETZ COLLART and MOREIRA, 1993). In the Guajará Bay, the cycle of rainfall and consequently of the largest tides, also follows an annual rate. According to Krumme and Liang (2004), tides are the main pulse in the areas of mangroves in the coastline of the State of Pará, inducing changes in the abundance of fish, shrimps and zooplankton, as well as promoting the export of wastes (SCHORIES et al., 2003) and bodies of water (DITTMAR and LARA, 2001). Thus, the strong exchanges between the compartments of the aquatic system occur more commonly during high tides, when the total abundance of species and richness and complexity of the nektonic community are larger (KRUMME et al., 2004).

In the case of Amazon shrimp, a great variability in length is observed. Notably, in this work we collected the biggest shrimp of the species ever recorded. On the lower Tocantins River, a maximum total length of 13.2 cm was observed; while in the artificial lake formed by the damming of the Tucuruí River, the maximum length recorded was only 8.0 cm (ODINETZ COLLART, 1987). Silva (2002) carried out studies on vigia Island and recorded a maximum total length of 14.1 cm. Odinetz Collart and MOREIRA (1993) found a specimen with 10.6 cm Island in the Central Amazon Careiro.

On the other hand, the average length for males and females (6.2 and 6.8 cm total length) was very close, but smaller than that recorded by Scott et al. (2002) –7 cm for males and 7.6 cm for females– and by Coelho et al. (1982), which was 8 cm for a commercial medium size. However, the average length was similar (6 cm) to that observed in the lower Tocantins River (ODINETZ COLLART, 1987), in Central Amazon (ODINETZ COLLART and MOREIRA, 1993), in Venezuela (ROMERO, 1982), and in dams of the State of Ceará (GUEST, 1979), and greater than the average of 5.5 cm recorded in Tucuruí Dam Lake (ODINETZ COLLART, 1987). Although slight genetic variations have been detected between populations of *Macrobrachium amazonicum* (VERGAMINI et al., 2011), it is believed that these variations in size can be explained by the flow speed of the rivers.

However, the size variations of *M. amazonicum* specimens are small. Generally, the individuals caught in flowing waters of large rivers have lengths greater than shrimp collected in calmer waters of floodplain lakes and dams (ODINETZ COLLART and MOREIRA, 1993).

High lengths observed in this study could be related to the fact that the Guajará Bay is an estuary where the specimens' growing conditions (food) and protection (refuge) are larger; in the same way that these environments are also used by adult shrimps for reproduction, where the larvae can feed on microorganisms, phytoplankton and zooplankton, which are very abundant in these environments. This can be a possible explanation for the largest sizes of shrimps found in the region of study, since the estuary is characterized by large transport of water, either by the tidal effects, as the flow of the rivers.

According to Martinelli (2005), preserving estuaries, preventing small-scale fisheries to be performed intensively in catches of younger shrimps and also ensuring the health of the waters without pollutants of any nature is essential for the maintenance and survival of shrimps, regarding marine shrimps as *Farfantepenaeus subtilis* (pink shrimp), *Xiphopenaeus kroyeri* (seabob shrimp) and *Litopenaeus schmitti* (white shrimp).

The smaller increase in body mass in relation to the carapace length of males, females and sexes together, shown by negative allometry, may be associated with gonadal maturation cycle of shrimps, since the species has continuous reproduction in the Amazon estuary (FREIRE, 2013). Fonteles Filho (1989) stated that another important factor that can influence the greater weight of the specimens is the stomach contents, which does not necessarily imply body weight increase. The data mentioned agree with those obtained by Flexa et al. (2005) regarding *M. amazonicum* in Cametá, Pará, and Silva et al. (2002) in Vigia. Bond and Buckup (1983) also found differences in this relationship for *M. borellii*. The same relationship was found for *M. iheringi* (LOBÃO and LONA, 1979). Carrying out studies in cultures of different intensities, Moraes Valenti and Valenti (2007) found that *M. amazonicum* has differentiated growth between sexes and between morphotypes in semi-intensive, intensive and highly intensive systems, always resulting in high productivity.

All morphometric relationships had positive allometry and the angular coefficient of regressions was different and greater than 1, i.e., the 'Y' axis grows to a proportion greater than the 'X' axis. The abdomen length gives the species two major advantages from ecological and economic points of view: according to Silva et al. (2004), there is a direct relationship between fertility and size in *Macrobrachium* specimens. The number of eggs varies in individuals of the same species, but increases in quantity with the size of the female. In this sense, a larger size of abdomen implies greater accommodation of eggs in the pleopods and, consequently, the possibility of a greater reproductive success, which can be considered as an advantage, taking into account the high mortality during the first larval stages. The larger size of females observed in this study suggests that the Amazon estuary is an important system for the maintenance of stocks of the species under study. It is assumed that larger females and consequently with greater amount of eggs adhered to the pleopods look for this site for the release of larvae, associating this site to a higher probability of survival of offspring, due to numerous areas of refuge (tide-channels) and the amount of organic matter in suspension. On the other hand, the economic advantage, and not necessarily environmentally friendly, is catching specimens of larger body size, ensuring local currency movement. However, we suggest caution when dealing with these two variables together, that is, ecological and economic sustainability.

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